# Studies on Thermal and Acoustic Properties of Areca Husk Fibers of Southern Shimoga Region of Western Ghat

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*Submitted by*

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# Studies on Thermal and Acoustic Properties of Areca Husk Fibers of Southern Shimoga Region of Western Ghat

## Introduction

Natural fibre research and development is attracting a lot of attention in modern science because of its lightweight, low density, and abundance. These are easily accessible, which attracts researchers to produce sustainable materials and aids enterprises in entering the market with ready-to-use items. Plant fibre's eco-friendliness and recyclable nature, along with mechanical properties comparable to synthetic fibres, has sparked increased interest in their use as a replacement for synthetic fibres in a variety of applications such as insulation boards, intermediate materials and so on [1]. Lignocellulose fibres are most commonly found in agricultural biomass, vegetable biomass, and plant residue, and can be extracted from wood, cereal straw, stems, roots, and fruit husks [2], [3]. Moreover, Natural fibers can be effective thermal insulators due to their ability to trap air pockets within their structure. When used in insulation, the fibers create a barrier that slows the transfer of heat between the inside and outside of a building, helping to maintain a comfortable temperature and reduce energy costs. Many Studies suggested that the natural fibre showed a lower thermal conductivity which can be utilized as the thermal intermediate materials[4]–[8]. In addition to this, Natural fibre are one of the best eco-friendly acoustic absorbers due to their porous and fibrous nature, which allows them to absorb sound waves. When sound waves pass through a material, they cause the material to vibrate, and this vibration creates noise. Acoustical absorbers work by reducing the amount of sound that reflects off surfaces and is transmitted through the air. Many researchers have shown that the natural fibre based material performs good stability towards the sound absorption, natural fibers can be a sustainable and effective choice for acoustic absorbers in various applications, from home theaters and recording studios to industrial and commercial settings [9]–[13].

These natural fibre-resin composites are lightweight, which makes them useful in applications where weight is a concern, such as in the aerospace industry. Natural fiber-reinforced composites are composite materials made by combining natural fibers with a resin matrix. The natural fibers are usually combined with a thermosetting or thermoplastic resin, such as polyester, epoxy, or polypropylene [2], [14]–[16]. Additionally, natural fibres are renewable and biodegradable,

making them an environmentally friendly alternative to synthetic fibres. Although, these natural fibre reinforced composites exhibit remarkable thermal and physical properties comparable to synthetic fibre composite materials [17]. Natural fibre reinforced composites having low density is a benefit for developing lightweight material with high mechanical properties [18], [19]. The fabrication of natural fibre- resin composites are gaining much attraction from the industrial and automobile sectors [20]. The Natural fibre reinforced composites having low density is a benefit for developing lightweight material with high mechanical properties[18], [19]. The superior physical and mechanical properties of fibre material affect the mechanical strength and durability of composite materials. These composites with superior mechanical, sustainable, light-weight properties made them to use in manufacturing automobile parts, construction field, packing industry and more. However, kenaf, jute, banana leaf or stem fibres are currently used in resin composites fabrication.

However, the hydrophilic nature of natural fibre affects the fibre-matrix bonding which influences the mechanical strength, thermal degradation and flexibility of the composite which can weaken the composite over time [21]. To mitigate this issue, researchers have developed surface treatments and coatings that can improve the durability of natural fibre-resin composites [19], [22]–[26]. There are several types of surface treatments have been introduced amongst them chemical treatment is one of the major and effective treatments which is following rapidly around the globe. The surface treatments change the morphology and the chemical composition of the natural fibres which alters its mechanical properties and made them to bond more intensely with the resin materials [27]–[29].

For the fabrication of composite materials polymer and resins are most widely used. The resin has the superior mechanical properties compared to polymers. Resins include epoxy, polyester, and phenolic resins. Resins have many desirable properties such as excellent adhesion, high strength, and resistance to water, chemicals, and temperature. However, the polyester resins are widely used for their excellent mechanical properties, such as high strength and stiffness, good chemical resistance, and low shrinkage. They are also easy to process, making them a popular choice for manufacturing composite materials. Polyester resins have a broad range of applications, including in the construction industry for making pipes, tanks, and other structural components. They are also widely used in the marine industry for manufacturing boats and other watercraft. Additionally,

the automotive industry uses polyester resins to make body parts and interior components. Moreover, the versatility of polyester resins has made them useful in the production of consumer goods such as furniture, sporting goods, and various household items. They can also be used as adhesive, coating, and casting materials. Due to their excellent properties and broad range of applications, polyester resins are widely used in many different industries [2], [30]–[32]. Despite of this the polyester resin is low-cost and easy to handle.

Areca, a monocotyledonous plant that belongs to palm species is one of the predominant commercial crops in India, primary states that cultivate areca as a major commercial crop are Karnataka (40%), Kerala (25%), Assam (20%), Tamil Nadu, Meghalaya, and West Bengal [33]. Areca fruit consists of a nut rounded by a thick layer of husk which is acts as a protecting layer [34]. The areca nut has a high market value, but the husks do not. These husks are discarded as an agricultural by-product; millions of tons of husks are produced each year and are utilised rarely as a source of home fuel. There are three varieties of husks produced by different areca farming practises: unripe, ripe, and dried.[35]. The areca husk is composed of two types of fibres: coarse and fine. The fine fibres are soft, thin and irregular in size. The Coarse fibres are thick, hard and uniform in size having much more mechanical strength. Areca husk's combination of fibres made it excellent for use in polymer composites, hardboard manufacture, and cushions, among other things [21]. The unripe areca fruit is dark green, and the husk contains more moisture and coarse fibre whereas ripen areca fruit is orange in colour, the husk is matured and contains less moisture compared to the unripe. The husk has moderate moisture and a mixture of fine and coarse fibres, and the ripe fruit is yellow. The dry areca fruit is brown, the husk is dry, the fibres have reduced density, and there are finer than coarse fibres. The physical and mechanical properties of the fibre change according to fibre maturity. [36].

Areca husk fibres (AHF) are composed of cellulose with varying amounts of hemicellulose from 35% to 65%, lignin 13% to 40%, pectin, wax and ashes [37], [38]. The high lignocellulosic fibre density slower the degradation rate and causes several environmental difficulties and a foul odour [39]. The roughness of the fibre enhances the mechanical strength and hardness of the composite materials [40]. The AHF can be used as raw materials in the manufacturing of hard boards, fluffy cushions, non-woolen fabrics and pressed boards [41]. To take advantage of AHF's capacity for industrial application, AHF can be introduced to polymer industries by reinforcing it with polymers

and resin matrix. Similarly, surface treatment for the AHF can change the mechanical strength, flexibility and the thermal properties of it [42]–[45]. In this present work detailed investigation was carried out on the utilization of the agro-waste AHF as thermal and acoustical absorber.

**Study area**

Southern Shimoga region of western ghat situated in southern part of Shimoga District. This region considered as one of the most rainfall regions in India. The region consists of Agumbe, Thirthahalli and Mastikatte where the extreme climate conditions are occurred. The region experiences heavy rainfall throughout the year, with the monsoon season extending from June to September. The average annual rainfall in Agumbe is around 7,620 mm (300 inches), with some years receiving even higher amounts. The temperature in Agumbe is moderate throughout the year, with average temperatures ranging from 20°C to 28°C (68°F to 82°F). The warmest months are typically April and May, with temperatures sometimes reaching 35°C (95°F). The coolest months are December and January, with temperatures sometimes dropping to 10°C (50°F).

This region is having the traditional practice of cultivating areca, the socio-economic lifestyle of this region directly depending on the areca crop where most of the people's income is either directly or indirectly come through the areca crop. In addition to this, the traditional practices of cultivating areca in this region generates the agro-waste areca husk in an enormous amount. The low temperature and heavy rainfall made the areca fruit to sustain for the extreme conditions and traditional practice of cultivating areca made the easy availability of good quality agro-waste areca husk for the study. The large-scale cultivation of areca in this region results in the generation of a significant amount of agro-waste areca husk, which is primarily due to the traditional methods employed for areca cultivation.

## Aim and objectives of the study

The aim of the study is to understand the behaviour of an agro-waste AHF as thermal insulating material and acoustical absorber in its raw form and reinforced composite. Additionally, the impact of fiber maturity and surface morphology has been assessed to gain insight into the behaviour of AHF and its composite. This study marks a significant step forward in the quest for sustainable, multi-functional materials. By harnessing the properties of agro-waste AHF, we can potentially address multiple environmental challenges simultaneously – reducing agricultural waste,

improving energy efficiency in buildings, and creating eco-friendly alternatives to synthetic insulation materials.

**The specific objectives are**

- To collect agro-waste areca husks and categorize them according to the maturity stages of their fibers.
- Undertake chemical treatment methods to alter the surface morphology of AHF.
- Examine the changes in surface morphology and chemical composition of chemically treated AHF. Investigate the alterations in the physicochemical properties and thermal degradation behaviour of the treated fibers.
- Evaluate the impact of chemical treatments and fiber maturity on the mechanical properties, thermal conductivity, and acoustical characteristics of AHF.
- To fabricate the treated AHF- Polyester resin composite and study the effect of chemical treatment and fibre maturity over mechanical, thermal and acoustical properties of composites.

**Methodology**

- The samples were collected from specific areas based on the desired level of fiber maturity (unripe, ripe, and dried).
- Retting Process is used to extract the fibres from the husk[43], [46], [47].
- The chemical treatment method is used to change surface morphology of the extracted AHF. Mercerization, Potassium Permanganate Treatment, Benzoylation, Acetylation and Acrylation treatment methods are followed [1], [22], [26], [38], [48].
- The morphological investigation of chemically treated AHF have been studied through Field effect scanning electron microscope (FESEM).
- The Chemical composition analysis of chemically treated and untreated AHF have been studied through X-Ray Diffractometer (XRD) and Fourier Transform Infra-Red Spectrometer (FTIR). The change in the crystallinity index and the chemical composition of the fibres have been observed respectively.

- The thermal degradation behavior of the untreated and the chemically treated AHF have been investigated through Thermo gravimetric Analyzer (TGA).
- The mechanical behavior of chemically treated AHF have been tested through Universal testing machine (UTM) by following Single fibre Tensile analysis ASTM D 3379-75.
- The AHF-Polyester Resin Composites are fabricated using with open metal moulds of dimension 300x300mm.
- The mechanical properties of the fabricated composites were analyzed through various tests. Tensile analysis (ASTM D 3039) and Flexural Analysis (ASTM D 790) were conducted using a Universal Testing machine. The hardness of the composites was tested using a Shore D hardness Analyzer (ASTM D 2240). The impact test of the composite materials was analyzed through the Izod (ASTM D256) – Charpy (ASTM D 785) method.
- The Thermal conductivity of AHF and AHF-Polyester resin composite are tested by a Lee's Disc Set Up [49]–[52].
- The Acoustical absorption analysis of AHF and AHF-Polyester resin composite have been carried through a Two Microphone impedance analyzer[13], [53].

## The Thesis outlines

The thesis entitled "Studies on Thermal and Acoustic properties of Areca Husk Fibers of Southern Shimoga region of Western Ghat" is divided into 4 chapters and the contents of each chapter is briefly explained below.

### Chapter 1: Introduction

In this chapter, a broad overview of natural fibers and their applications will be provided, including a detailed literature survey of the advantages and uses of lignocellulosic fibers. The chapter also explores how natural fibers can be utilized for thermal insulation and acoustical absorption. Additionally, the chapter delves into the application of natural fiber composite materials and discusses the benefits of fiber surface morphology. The chapter also give the information regarding the areca crop and the agro-waste producing by the cultivation methods. The detail information of study area will be provided. The chapter concludes by presenting the objectives of the work and outlining the structure of the thesis.

**Chapter 2: Materials and Methods**

In this chapter, the focus is on the collection of materials and the experimental methodologies used. The chapter provides specific details on the location where the samples were obtained. Furthermore, various chemical treatment methods such as Mercerization, Potassium Permanganate Treatment, Benzoylation, Acetylation and Acrylation have been described. The chemical composition, thermal degradation, mechanical, hardness, impact, acoustic and thermal conductivity of AHF and its polyester composite have been examined to gain a deeper understanding. To accomplish this, several characterization techniques were employed, including XRD, FTIR, TGA, UTM, Izod-Charpy Impact analyzer, Shore D hardness tester, Lee's Disc Set up and Two microphone impedance analyzer setup.

**Chapter 3: Result and discussion**

This chapter deals with the morphological, chemical composition and thermal degradation behavior of chemically treated AHF and untreated areca husk fibre. The morphology of chemically treated AHF is investigated by FESEM. It can clearly show that the change in the surface with respect to the chemical treatments. The chemical composition behavior of AHF is studied through XRD and FTIR analyses to determine changes in crystallinity and chemical composition. Additionally, this chapter provides insights into the effects of chemical treatment on the surface morphology and chemical composition of AHF. Furthermore, the chapter presents the crystallinity index and chemical composition of both unripe and ripe AHF. In addition, this chapter also reveals the thermal degradation behavior of chemically treated AHF. This chapter further examines the effect of chemical treatment on the mechanical, acoustical, and thermal conductivity properties of AHF with respect to their maturity level. The mechanical property of the chemically treated AHF is studied through Single Fiber Tensile Analysis to determine their strength following various chemical treatments. The acoustical absorption property of the chemically treated AHF is investigated using Two Microphone Impedance Tube with a frequency range of 100-2000Hz, which provides the sound absorption coefficient (SAC) value to understand the material's behavior to the incident frequency. Furthermore, the chapter explains the Thermal Conductivity of the

chemically treated AHF using Lee's Disc Set up. The chapter also discusses the impact of fiber maturity on these results.

This chapter also outlines the fabrication process of the composite material using chemically treated AHF and polyester resin. The chapter presents the mechanical strength, impact strength, hardness, acoustical absorption, and thermal conductivity behavior of the AHF-polyester resin composite. The mechanical property analysis is conducted using the UTM to test the tensile and flexural strength of the composites. The impact analysis is performed through the Izod-Charpy method, and the hardness is measured using the Shore D hardness analyzer. The acoustical absorption behavior of the composite is studied using the Two Microphone Impedance Tube, while the Lee's Disc Set up is used to investigate the thermal conductivity of the material. Additionally, the chapter discusses the impact of fiber maturity and surface treatment of the AHF on the composite material's properties. In conclusion, the study identifies suitable chemical treatments for the AHF to enable its use in specific applications.

**Chapter 4: Summary and Future scope.**

The main findings of the study are summarized in this chapter, along with recommendations for suitable chemical treatments for specific applications to utilize agro-waste AHF as a useful product. Additionally, the chapter emphasizes the importance of continuing the current work and highlights potential future research directions.

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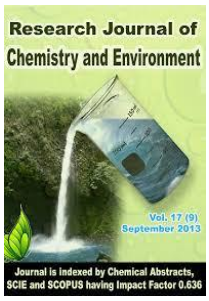
# List of Publication

## In Peer reviewed Journal

## Part of the thesis

1. 
Research Journal of
Chemistry and Environment
Vol. 17 (9)
September 2013
Journal is indexed by Chemical Abstracts,
SCIE and SCOPUS having Impact Factor 0.636

**Chethan G.,** Sunil K.C., Achary Sandesh, Narayana Y. (2020) Determination of thermal conductivity of Areca husk fiber by Lee's disc method. *Research Journal of Chemistry and Environment*, 24(I), 17–21.

2.


**Chethan G.,** Narayana Y., & Sunil K.C. (2022) Development and characterization of low thermal conductive material from reinforced areca husk fibre composite. *Composites: Mechanics, Computations, Applications: An international Jouranal* vol 13 issue 3 pp 87-100. 10.1615/CompMechComputApplIntJ.2022043114.

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**Chethan G.,** Sunil K.C. & Narayana Y. (2023) Effect of Surface Modification on the Impact Strength and Hardness of Areca Husk Fibre Reinforced Polyester Resin Composite. *Materials Science Forum.* Vol 1083, pp 105-110. http://dx.doi.org/10.4028/p-31h8t9.

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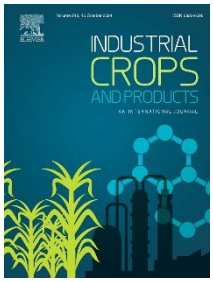
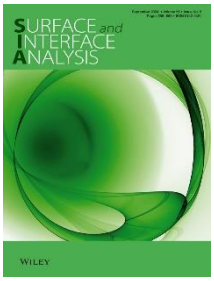
**Chethan G**., Sunil, K. C., Maddani, M. R., & Narayana, Y. (2023). A Study on Shore D Hardness of Areca Husk Fibre Reinforced Polyester Resin Composite: Impact of Fibre Maturity. *Materials Science Forum* (Vol. 1111, pp. 83–88). Trans Tech Publications, Ltd. https://doi.org/10.4028/p-inpop0.

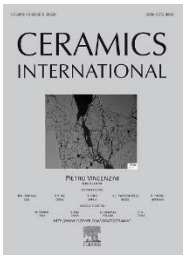
5. 


**Chethan G.** & Narayana Y. Conversion of agro-waste Areca Husk Fiber into an eco-friendly thermal insulator. *Industrial crops and products.* INDCRO-D-24-02369R1 (Revised Manuscript Submitted)

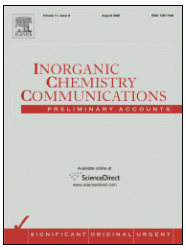
6. 


**Chethan G.** & Narayana Y. Unraveling the role of surface morphology on mechanical and impact strength of Areca husk fibre -Polyester resin composite. *Surface and Interface Analysis.* SIA-24-0219 (Communicated)

## Other related Publication

1. 


Sunil, K. C., Utsav, S., Nairy, R. K., **Chethan, G.,** Shenoy, S. P., Mustak, M. S., & Narayana, Y. (2021). Synthesis and characterization of $Zn_{0.4}Co_{0.6}Fe_2O_4$ superparamagnetic nanoparticles as a promising agent against proliferation of colorectal cancer cells. *Ceramics International*, 121(March), 93–102. https://doi.org/10.1016/j.ceramint.2021.03.248

2. 


Sunil, K. C., Suvarna, S., Chatterjee, J., **Chethan, G.,** Mustak, M. S., & Narayana, Y. (2021). Glucose-derived rGO/Zn0.4Co0.6Fe2O4 superparamagnetic nanohybrid: Synthesis, characterization and evaluation of cytotoxicity. *Inorganic Chemistry Communications*, 129, 108629. https://doi.org/10.1016/j.inoche.2021.108629

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Sunil, K. C., Suvarna, S., Nairy, R. K., **Chethan, G.,** Mustak, M. S., & Narayana, Y. (2020). Facile, cost-effective and eco-friendly synthesis of carbonyl-rich partially reduced graphene oxide using glucose as a sole precursor. *SN Applied Sciences*, 2(8), 1323. https://doi.org/10.1007/s42452-020-3134-0.

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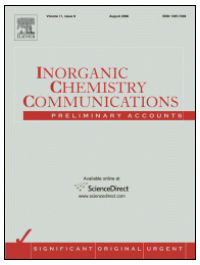
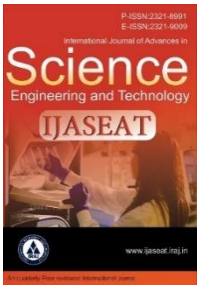
Sunil, K. C**., Chethan, G.,** Suvarna, S., Nairy, R. K., Mustak, M. S., Chatterjee, J., & Narayana, Y. (2019). Synthesis and Characterization of Biocompatible Zn0.4Co0.6Fe2O4 Nanoparticles. *JETIR*, 6(5), 431–433. https://doi.org/http://www.jetir.org/papers/JETIRCU06088.pdf

5 


Sunil K.C., Ashwini Prabhu, Rajesha K. Nairy, Saritha Suvarna, **Chethan G**, Mohammed S. Mustak & Narayana Yerol. (2023) Potential of moderate-Z superparamagnetic nanoparticles in improving the efficacy of cancer theranostics. *Inorganic chemistry communications,* 158, part 1, https://doi.org/10.1016/j.inoche.2023.111491.

6. 


Malleshi Kavasara, Sandesh Achari, **Chethan G,** Prakash M M, Vinutha P. R., Kaliprasad C. S. & Narayana Y (2023) Radium and Radon exhalation rate in soil samples of Davanagere district of Southern India. *International journal of Advances in Science Engineering and Technology,* 65-71, 10. https://iraj.doionline.org/dx/IJASEAT-IRAJ-DOIONLINE-19358

**Conference /Symposium Presentation**

1. **Chethan G.,** Sunil K.C., Rajesh Nairy, Narayana Y. Synthesis and cytotoxicity study of manganese-ferrite superparamagnetic nanoparticles. International conference on Radiation Biology held from 4 to 6 October 2018 at KS Hegde Medical Academy, Delarakatte, Mangalore.

2. **Chethan G.,** Sunil K.C. & Narayana Y. Extraction of fibers from unripe, ripe and dried areca husk of southern Shimoga region on the western ghats. International conference on Advanced functional materials for Energy, Environment and Health Care (AFMEEHC) held at Vijnan Bhavan, Mysore during 18-20 March 2019.

3. **Chethan G.,** Sunil K.C., Sandesh Achary, Narayana Y. Determination of thermal conductivity of Areca husk fiber by Lee's disc method. CSIR Sponsored Third International

conference on Renewable energy and sustainable environment (RESE 2019) held from 12 to 14 December 2019 at Dr. Mahalingam College of Engineering and Technology, Pollachi.

4. **Chethan G.,** Narayana Y., & Sunil K.C. Development and characterization of low thermal conductive material from reinforced areca husk fibre composite. International conference on Futuristic Advancements in materials, manufacturing and thermal sciences (ICFAMMT 2022) held at IITRAM Ahmedabad, Gujarat from January 20-22, 2022.

5. **Chethan G.** & Narayana Y. Novel approach to utilize agro-waste areca husk to enhance the soil fertility. Shodh-Shikar 2022 "All India Inter University Competition of Research and Innovation" held at Rabindranath Tagore University, Bhopal, Madya Pradesh from 25-26 March 2022.

6. **Chethan G.,** Sunil K.C. & Narayana Y. Effect of Surface Modification on the Impact Strength and Hardness of Areca Husk Fibre Reinforced Polyester Resin Composite. 5$^{th}$ international conference on Advanced composite materials (ICACM 2022) held at Hosei University, Tokyo, Japan from August 24-26, 2022.

7. **Chethan G.,** Sunil K.C. Maddani M.R. & Narayana Y. Study on the surface morphology of chemically modified areca husk fibre. International conference on Advanced Materials, Metallurgy & Manufacturing 2022 held at PEC, Chandigarh from November 1-2, 2022.

8. **Chethan G.,** Sunil K.C. Maddani M.R. & Narayana Y. A study on Shore D Hardness of Areca Husk Fibre Reinforced Polyester Resin Composite: Impact of Fibre maturity. 11$^{th}$ International Conference on Nano and Material Science held at Nanyang Technical University, Singapore from January 13-15, 2023.